Leeghwaterstraat 44
2628 CA Delft
P.O. Box 6012
2600 JA Delft
The Netherlands

www.tno.nl

T +31 88 866 22 00

TNO report

TNO 2016 R11409

Natural cooling in dwellings
Model research concerning energy saving and thermal comfort improvement

PUBLIC SUMMARY

Date	8 December 2016
Author(s)	Wim Kornaat
Number of pages	6
Sponsor	DUCO Mr. S. Verbrugge Handelsstraat 19 8630 Veurne België
Project number	060.21343

All rights reserved.
No part of this publication may be reproduced and/or published by print, photoprint, microfilm or any other means without the previous written consent of TNO.

In case this report was drafted on instructions, the rights and obligations of contracting parties are subject to either the General Terms and Conditions for commissions to TNO, or the relevant agreement concluded between the contracting parties. Submitting the report for inspection to parties who have a direct interest is permitted.

© 2016 TNO

1. Introduction

The increasing demands on energy efficiency of dwellings has led to lower energy needs for heating but at the same time increasing energy needs for cooling over the last couple of years. DUCO is investigating the possibilities to reduce the cooling need by application of automatic systems for ventilative cooling in combination with solar shading. DUCO has asked TNO to perform a model research to determine the potential of such systems for energy saving and thermal comfort improvement.

The main results of this model research are described in this public summary, which is based upon the full report TNO 2015 R11524.

2. Study

The model simulations are performed for a typical Dutch dwelling (see figure 1). This dwelling is attached on both sides to identical dwellings.
The simulations are performed with TRNSYS, using the TRNSYS building model in combination with TRNFlow.

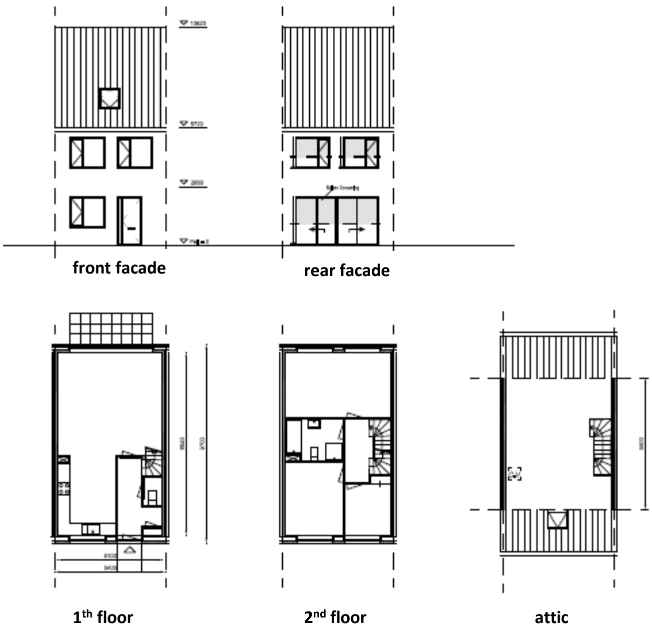


figure 1: Dwelling layout

The dwelling has an energy performance coefficient of 0.4. This is a figure for the nowadays maximum allowed energy consumption of a dwelling in the Netherlands depending on the floor surface and building envelope surface.
The following properties apply to this dwelling:

- external wall: R_c= 5.0 m^2K/W.
- roof: R_c= 7.0 m^2K/W.
- floor: R_c= 3.5 m^2K/W.
- window: U= 1.65 W/m^2K (incl. window frame).
- ventilation: system C (mechanical exhaust in kitchen, bathroom and toilet in combination with natural supply via ventilation grids in the various rooms).
- airtightness: $q_{v,10}$= 87 dm^3/s, $q_{v,10, spec}$= 0.7 $dm^3/s/m^2$ (leakage at 10 Pa).

- occupancy: 4 persons (2 adults, 2 children).
- heating: HR107 boiler
- cooling: no active cooling

3. Ventilative cooling system
The ventilative cooling system of DUCO makes use of:
a) the available ventilation system C.
b) additional ventilation provisions installed in all the rooms and the attic.

These provisions are controlled by the control algorithms of the DUCO system based upon the indoor air temperatures.

The additional provisions are burglar proof, rain proof (do not allow entry of rainwater) and wind proof. The capacity of these provisions is expressed as the air change rate of the adjacent room at an certain prescribed pressure difference. Without further information, it is noted that these provisions are substantial larger than the standard ventilation grilles, being part of the ventilation system C.

4. Solar shading
The rear façade is orientated on the south. Solar shading is thus assumed to be present in the living room and large bedroom (bedroom1) on 2^{nd} floor.
Various controls are simulated, depending on the solar radiation on the façade and indoor air temperature.

5. Overview of system configurations
In table 1 an overview of the system configurations is given, which is a selection made from the various system configurations considered in the underlying report that is the basis for this public summary.

table 1: Overview of the system configurations

Number	Name	description
1	ref	reference situation
2	manual_5ach	manual use additional ventilation provisions in bedrooms during the night. design: 5 air changes per hour(1)
3	duco_5ach	ventilative cooling DUCO system design:5 air changes per hour(1)
4	duco_10ach	ventilative cooling DUCO system design:10 air changes per hour(1)
5	duco_5ach_shading	Ventilative cooling according to 3 plus solar shading if solar radiation>300 W/m^2 and Tinside>22°C
6	duco_10ach_doors	in addition to 4 also internal doors opened

note: (1) Size of provisions is given in air changes per hour for the adjacent room at a defined pressure difference. This is not a measure for the actual realised ventilation level in time.

6. Results

In figure 2 the energy demand for cooling over a year is given. According to the Dutch standards (active) cooling to an indoor temperature of 24°C is simulated.

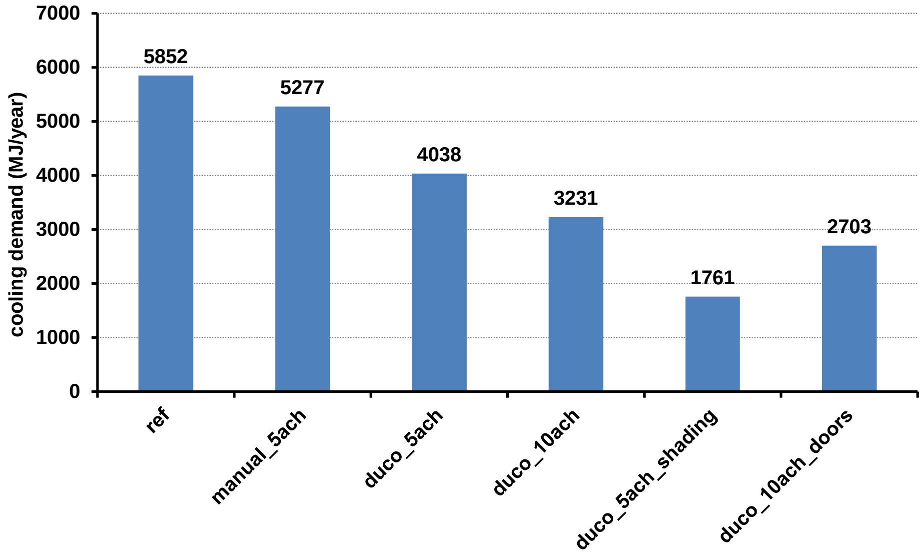
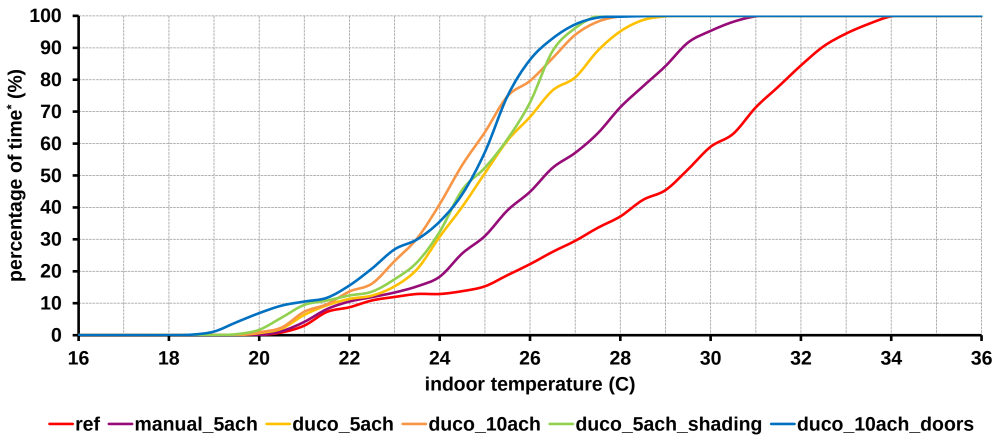


figure 2: Energy demand for cooling

To determine the effect of the ventilative cooling and/or solar shading on thermal comfort, cumulative histograms of the occurring indoor air temperature are made. In figure 3 such a histogram is given for bedroom1 (sunside) during the night depending on the ventilative cooling and solar shading configuration.



** percentage of time indoor air temperature is lower than indicated value*

figure 3: Cumulative histogram of indoor air temperature in bedroom1 during the night depending on the ventilative cooling and solar shading configuration

The effect on the indoor air temperatures in the various rooms are summarised in figure 4. In this figure the range of the indoor air temperature is given that is exceeded 50% (low value) to 10% (high value) of the time.

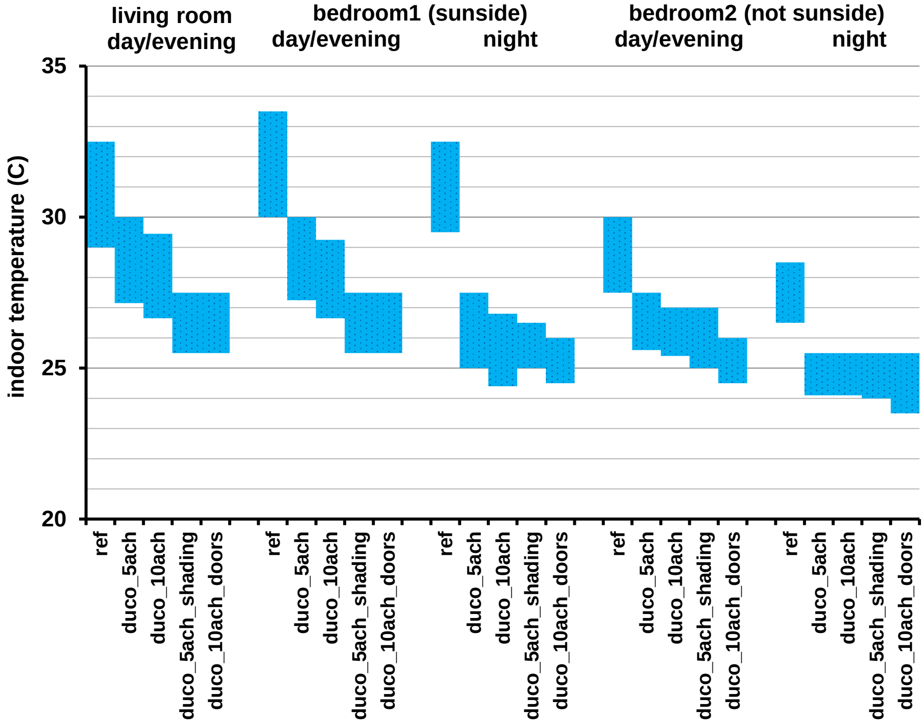


figure 4: Range of indoor air temperature that is exceeded 10 to 50% of the time depending on the ventilative cooling and solar shading configuration

7. Discussion of the results

The model research clearly shows that the use of ventilative cooling and/or solar shading leads to a large decrease of the cooling demand (see figure 2).
With the DUCO ventilative cooling system the cooling demand of the simulated dwelling can be reduced with 30% to 40% depending on the size of the additional ventilation provisions. In combination with solar shading even more reduction, up to 70%, can be realised.
Furthermore a large decrease of the indoor temperatures and thus improvement of the thermal comfort can be obtained in the dwelling (see figure 4).

The simulations show that for the control of shading both the solar radiation and the indoor air temperature have to be taken into account. Otherwise during colder periods, the use of the shading may lead to an increase of the heating demand.

Windows in dwellings, at least in opened position, are normally not burglar, rain and/or wind proof. Manual airing with windows during the night is therefore likely to be limited to the used bedrooms in situations with calm weather. The simulations assuming only use of the windows in the bedrooms, with however similar dimensions as the additional provisions in the automatic DUCO ventilative system, show little effect of such manual use on cooling need and comfort. This subscribes the need for a burglar, rain and wind proof automatic controlled system for ventilative cooling.

Signature

Delft, 8 December 2016

TNO

Frank Driessen
Research Manager ad int.
Heat Transfer and Fluid Dynamics

Wim Kornaat
Author